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Performance of PV/Wind/Battery Hybrid Power System using Different MPPT Techniques

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***Abstract*- Renewable energy sources have become a popular alternative electrical energy source where power generation in conventional ways is not practical. In the last few years the photovoltaic and wind power generation have been increased significantly. In this study, we proposed a hybrid energy system which combines both solar panel and wind turbine parameter to generate electrical power source of electrical and supplied to power grid station. Two control techniques are used to maximum power point tracking (MPPT). It is used in circuit wind turbine as well in solar to get maximum power. And second control technique is used at grid side converting DC-AC by voltage source converter. A simple control technique which is also cost effective has been proposed to track the operating point at which maximum power can be coerced from the PV system and wind turbine generator system under continuously changing environmental conditions. The entire hybrid system is described given along with comprehensive simulation results that discover the feasibility of the system. A software simulation model is developed in Matlab/Simulink.**

Key Word— Maximum Power Point Tracking (MPPT); Photovoltaic cell; Hybrid Power System; Power Wind battery

1. Introduction

Due to depletion of fuel supply like gas and coal, development in renewable energy sources is unceasingly rising. This can be the explanation why renewable energy sources front emphasize across the world. Energy is important to the economic process and social development of any country [1]. Native energy resources ought to be developed to the optimum level to attenuate dependence on foreign fuels, subject to breakdown economic, environmental and social constraints. This light-emitting diode to a lift in analysis and development similarly as investment in renewable energy trade in search of the way to satisfy energy demand and to scale back dependency on fossil fuels. Wind and alternative energy are getting in style attributable to abundance, accessibility and simple harnessing for power generation. This thesis focuses on Associate in Nursing integrated hybrid renewable energy system consisting of wind and alternative energy [2].

Electricity is important for contemporary society. There are 2 sources of electricity generation from standard are non-conventional energy resources. Electricity demand will increase thus swe have to be compelled to fulfill demand to come up with electrical energy [3]. currently a day's electricity is generated by the standard energy resources like coal, diesel, and nuclear etc. the most disadvantage of those sources is that it produces waste like ash in coal station, nuclear waste in atomic energy plant and taking care of this wastage is incredibly expensive. And it conjointly damages the character [4].

Hybrid power systems (HPS) are autonomous electricity generating systems that incorporate quite one variety of power sources that operated along with associated supporting instrumentation to produce wattage to the grid or on website. Through this integration of various energy sources in one provide system, the technology of coupling provides an ideal risk to use domestically obtainable renewable energy sources for provision wattage in remote locations [5]. Hybrid system technology principally covers complete systems similarly as island grids of tiny and medium power ranges. All told cases, it contains 2 or additional power generation sources so as to balance every other's strengths and weaknesses [6].

2. Photovoltaic Energy System

In 1839, a French physicist Edmund Becquerel proposed that few materials have the ability to produce electricity when exposed to sunlight. But Albert Einstein explained the photoelectric effect and the nature of light in 1905. Photoelectric effect state that when photons or sunlight strikes to a metal surface flow of electrons will take place. Later photoelectric effect became the basic principle for the technology of photovoltaic power generation. The first PV module was manufactured by Bell laboratories in 1954 [7].

2.1. Working of PV Cell

The basic theory involved in working of an individual PV cell is the Photoelectric effect according to which, when a photon particle hits a PV cell, after receiving energy from sunbeam the electrons of the semiconductor get excited and hop to the conduction band from the valence band and become free to move [8]. Movement of electrons create positive and negative terminal and also create potential difference across these two terminals. When an external circuit is connected between these te`rminals an electric current start flowing through the circuit shown in figure 1.

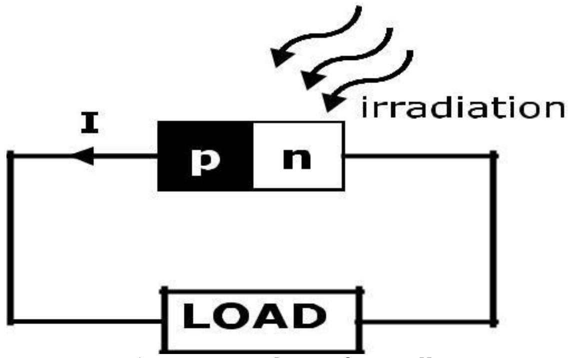

Figure 1. Working of PV cell

3. MPPT Control Technique

The HCS MPPT control method presented in [16] combines the benefits of two of the commonly used MPPT methods first is the tracking method based on the optimum power versus speed characteristic and second the HCS. The algorithm measures generator rotor speed and computes optimum torque T_{opt}, the torque which maximizes power [17]. A simple HCS method is proposed wherein output power information required by the MPPT control algorithm is obtained using the dc link current and generator speed information. These two signals are the inputs to the MPPT controller whose output is the command speed signal required for maximum power extraction. The optimum speed command is applied to the speed control loop of the grid side converter control system. The HCS control method presented in [18] operates the generator in speed control mode with the speed reference dynamically modified in accordance with the magnitude and direction of change of active power [9].

4. Simulation tool and Software

MATLAB: The MATLAB is a high-performance language for practical calculating. It incorporates computation, visualization, and programming in an easy-to-use environment where problems and answers are communicated in used to mathematical representation [10]. MATLAB is used as a simulation tool for the network arrangement set up and for setting up the data transmission between numerous nodes present in the network. MATLAB core programming and commands are used as a simulation tool. MATLAB is a software program that permits you to do data manipulation and visualization, calculations, math and programming. It can be used to do very simple as well as very sophisticated tasks [11], [15].

4.1 About MATLAB

MATLAB is an interactive system for doing numerical computations.

- A numerical analyst called Cleve Moler wrote the first version of MATLAB in the 1970s. It has since evolved into a successful commercial software package [19].
- MATLAB relieves you of a lot of the mundane tasks associated with solving problems numerically. This allows you to spend more time thinking, and encourages you to experiment.
- MATLAB makes use of highly respected algorithms and hence you can be confident about your results.
- Powerful operations can be performed using just one or two commands.
- You can build up your own set of functions for a particular application.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN [20].

MATLAB language: This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs [21].

MATLAB working environment: This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications [12], [22].

5. Simulation and Test Results

The main Simulink model of the test system is given in Figure-2. The system consists of PV/Wind/Battery Hybrid Power System to maintain and sustain the continuity of supply to the load on demand at all times, the outputs of wind energy and solar energy are integrated suitably [13].

For wind generator, the overall operation is based on the estimation of the speed that is basically a sensor-less rotor speed estimator, which in fact avoids all mechanical sensors. The rotor speed so estimated, is used to control the turbine speed by maintaining the input dc quantities (Voltage and Current) for boost converter [14].

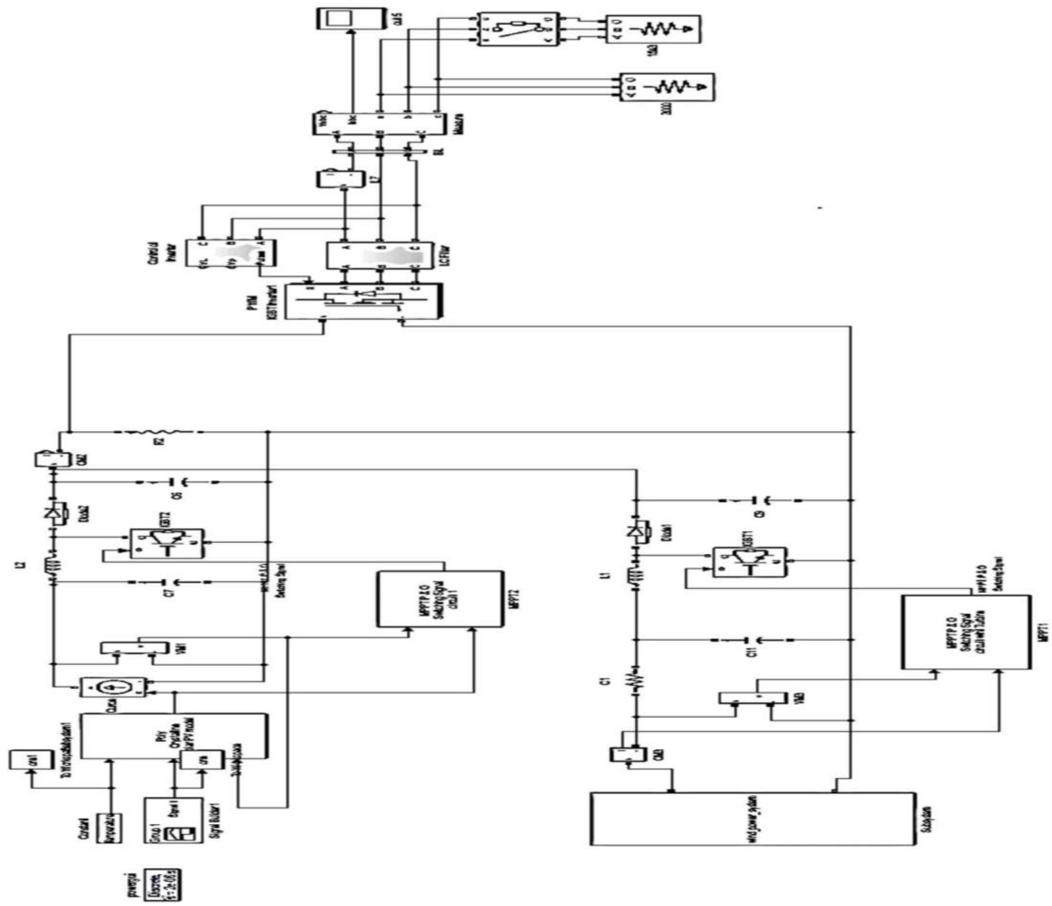

Figure 2. PWB-HPS Model

Figure 3 is a switching signal for boost converter which is obtain by MPPT (P&O) which have 1kHz switching signal by this switching signal system got maximum power by mppt.

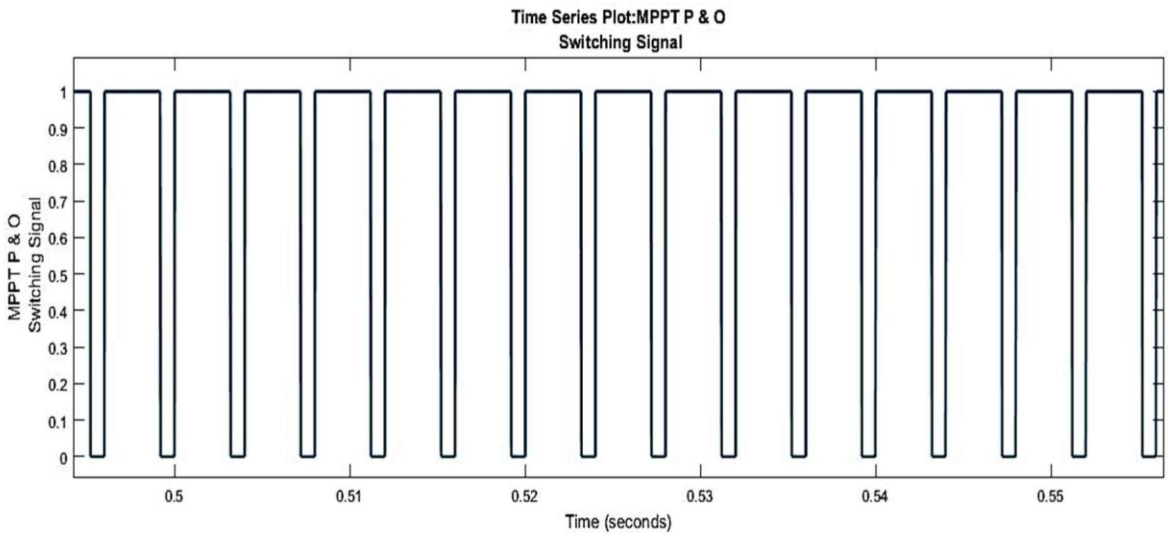

Figure 3. Switching signal of MPPT

Figure 4 represents the solar input temperature which is taken by sun to solar PV model which is 25*c at every seconds vertical axis represents temperature amplitude and horizontal axis time in seconds.

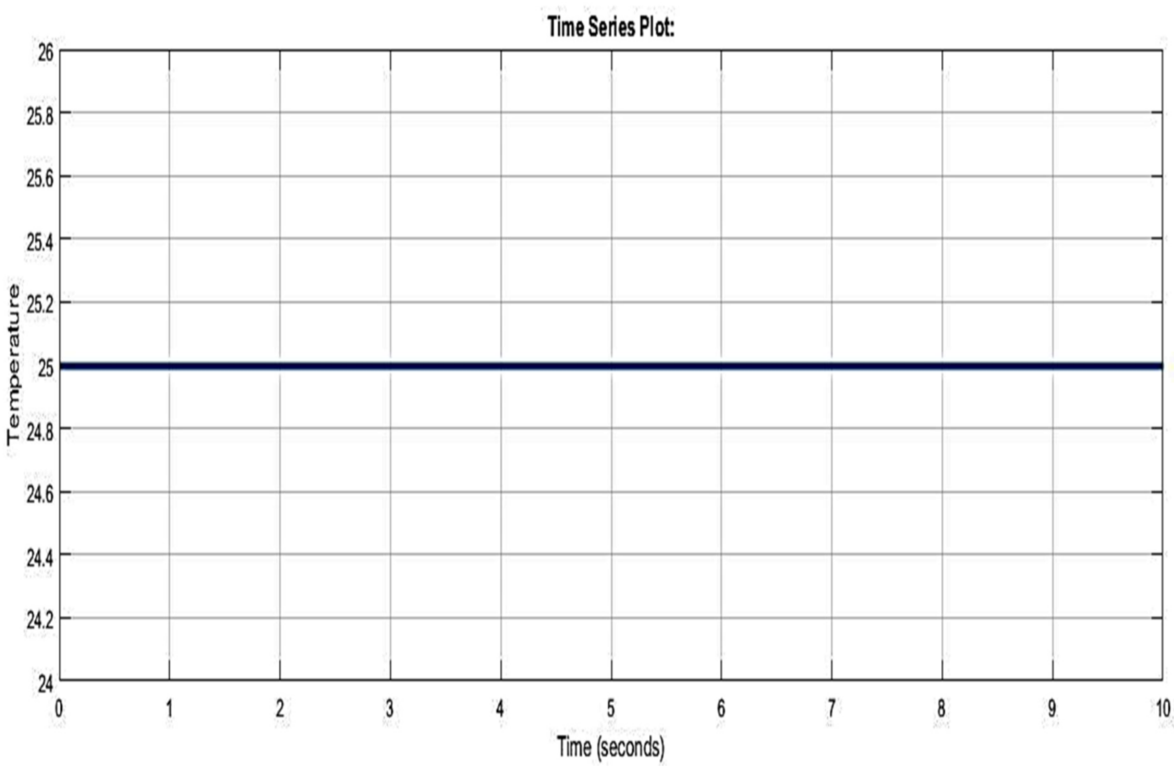

Figure 4. Solar Temperature at every seconds

Figure 5 PV solar output in variation of solar irradiance at 1 second solar irradiance changes the vertical axis represents solar output voltage and horizontal axis represents time in seconds.

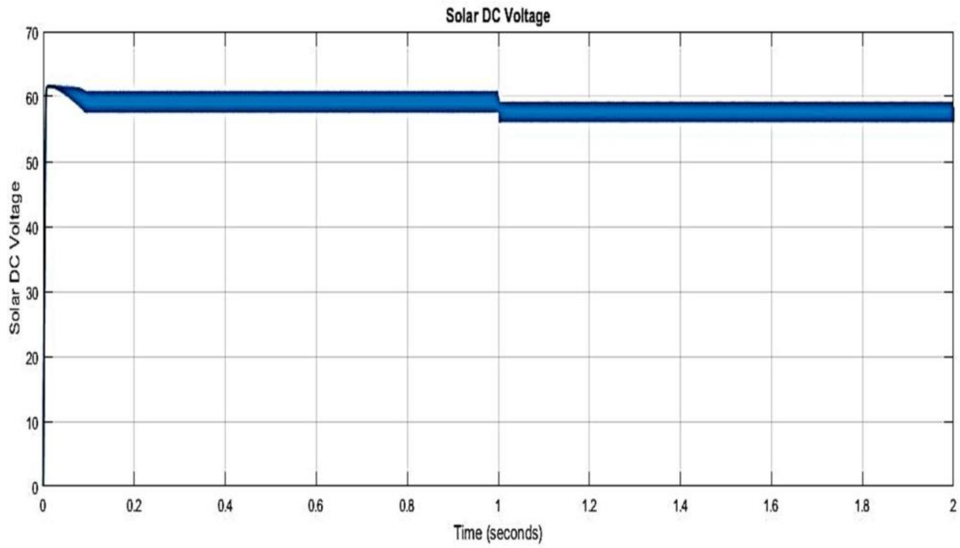

Figure 5. PV Array Voltages

In figure 6 shows a PV array Power and also shows a PV array output power at constant wind speed horizontal axis represents time in seconds and vertical axis represents solar power at constant wind speed but variable solar irradiance at 0 to 1 seconds solar irradiance is $1000 w/m^2$ at 1 seconds to 2 seconds solar irradiance is $900\ w/m^{2.}$

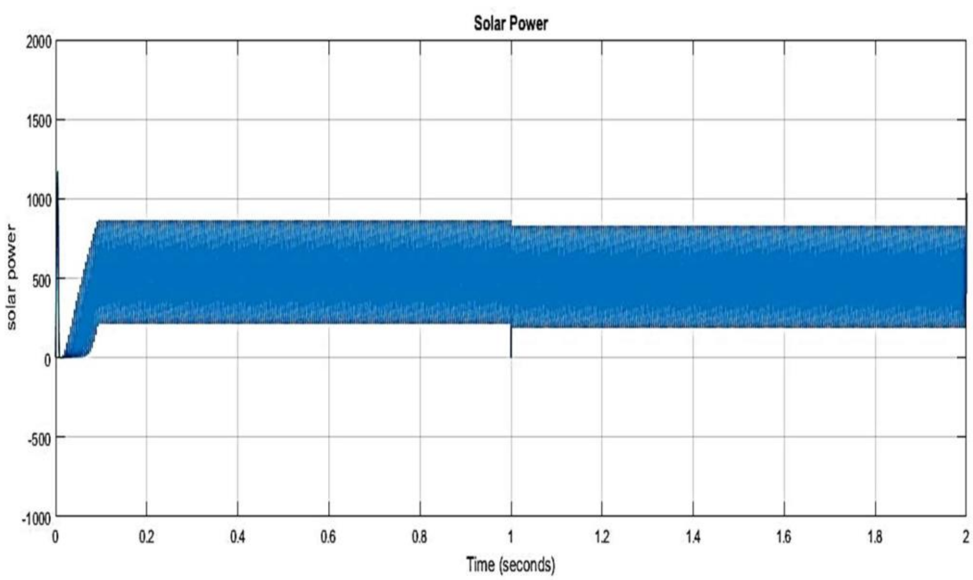

Figure 6. PV Array Output Power

In figure 7 shows a PV Boost DC voltage the voltage is 375 VDC with 10% overshoot Horizontal axis represents time in seconds and vertical axis represents solar DC-boost voltage the voltage is boost by help of MPPT switching signal.

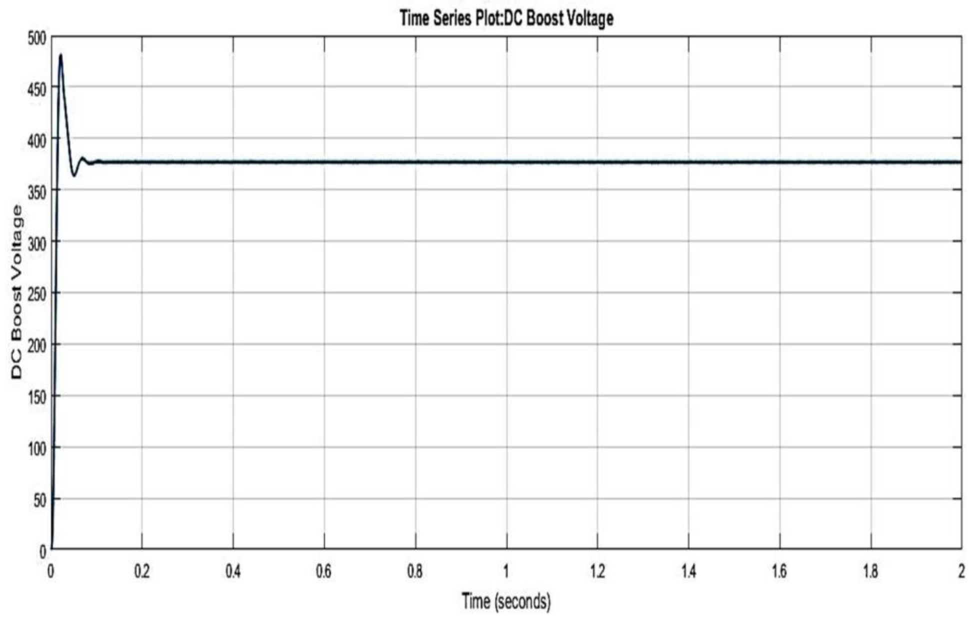

Figure 7. PV Boost DC Voltage

In figure 8 represents PV Array voltages at variable constant wind speed but variable soar irradiance horizontal axis represents time in seconds and vertical axis represents solar DC-voltage at constant wind speed but at variable solar irradiance at 0 to 1 seconds solar irradiance is 1000w/m^2 at 1 seconds to 2 seconds solar irradiance is 900 w/m^2.

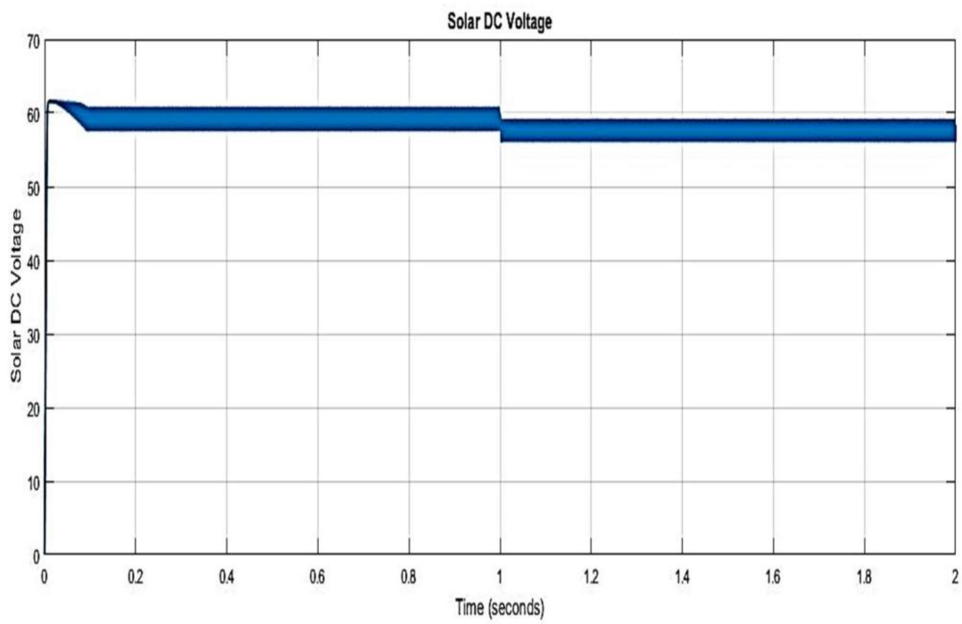

Figure 8. PV Array voltages

In figure 9 shows wind Output Power with Controller (MPPT) 8kw is output power by the help of maximum power point tracking in this irradiance horizontal axis represents time in seconds and vertical axis represents solar DC-Power at constant wind speed but at variable solar irradiance at 0 to 1 seconds solar irradiance is 1000w/m^2 at 1 seconds to 2 seconds solar irradiance is 900 w/m^2.

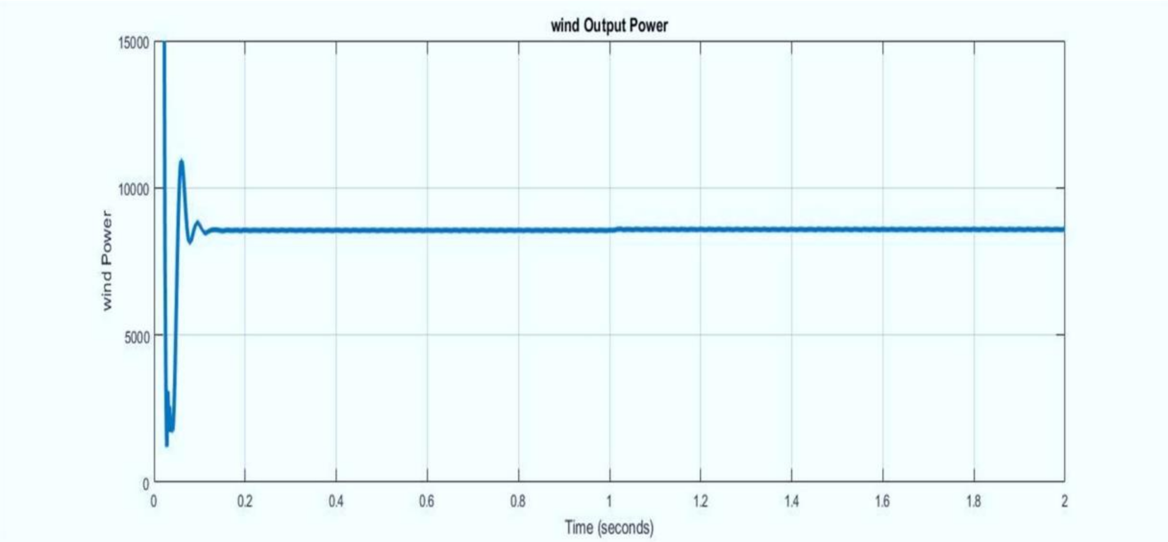

Figure 9. Output Power at variable wind speed

5.1. Output Current/ Voltage

In figure 10 shows one phase inverter current of over three Phase AC inverter Current horizontal axis represents time in seconds and vertical axis shows Sinusoidal one phase current of three phase inverter having amplitude 15A. The frequency of sinusoidal current signal is 50Hz. And it is stable at 0.05 seconds with 2% THD.

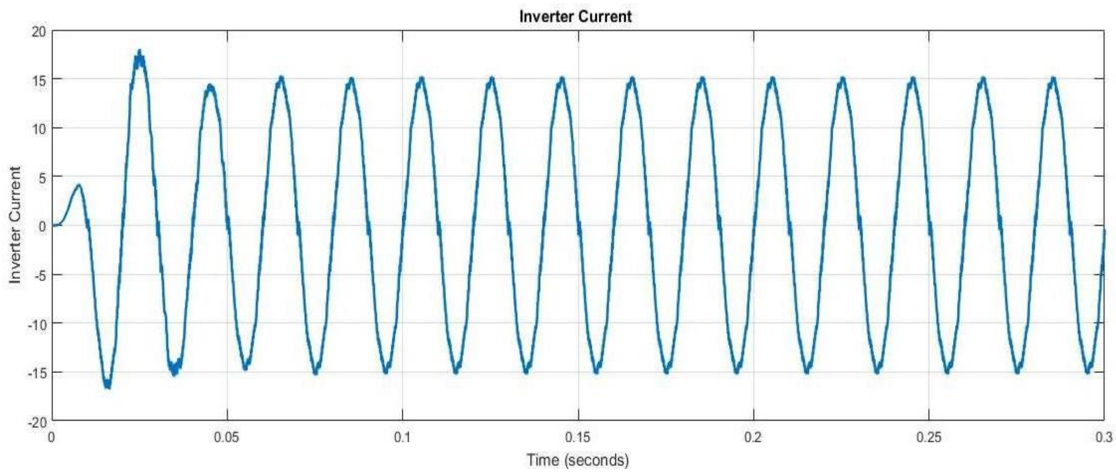

Figure 10. Single phase inverter load current

In figure 11 shows inverter current of three Phase AC inverter Current and horizontal axis represents time in seconds and vertical axis shows Sinusoidal three phase inverter current having amplitude 15A. The frequency of sinusoidal current signal is 50Hz. And it is stable at 0.05 seconds with 2% THD.

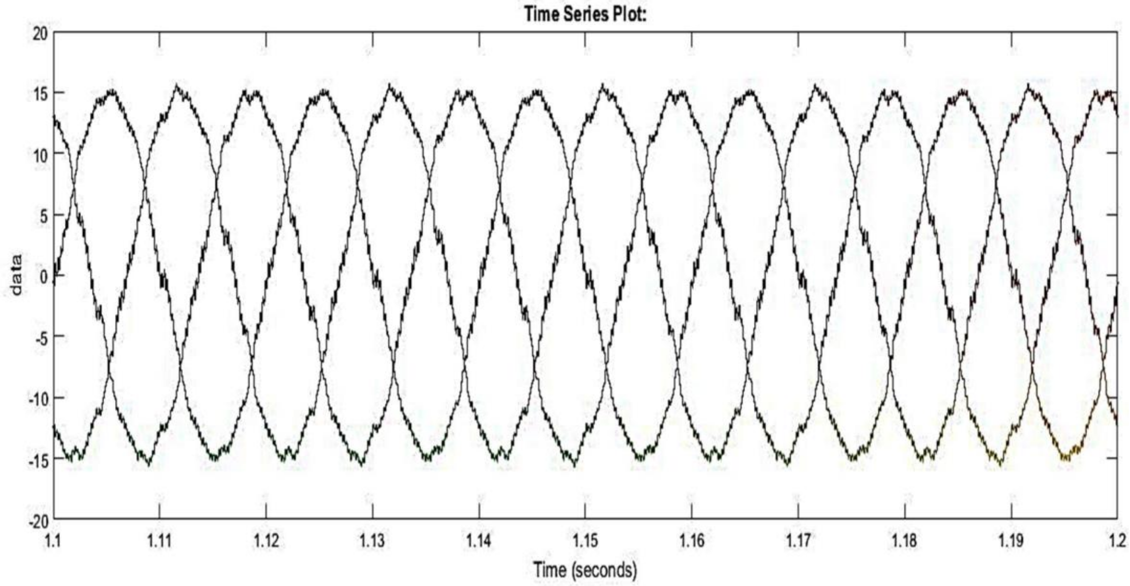

Figure 11. Three Phase AC Current

In figure 12 shows inverter line voltage of three Phase AC inverter voltage and horizontal axis represents time in seconds and vertical axis shows Sinusoidal three phase inverter line voltage having amplitude 375VDC. The frequency of sinusoidal current signal is 50Hz.

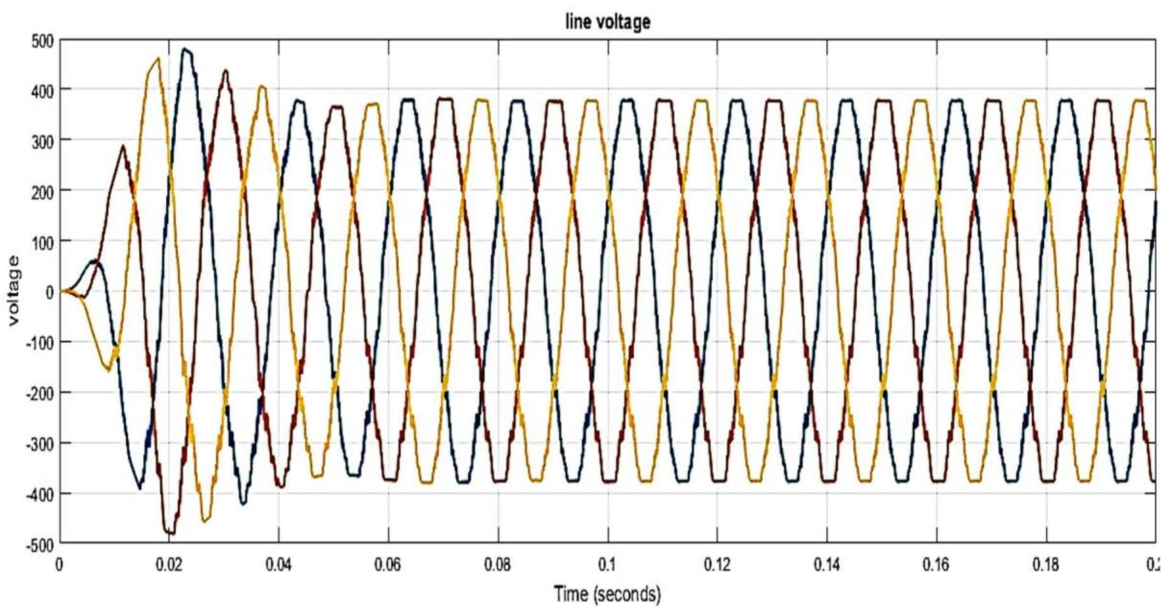

Figure 12. Three Phase AC Voltage

5.2. Wind Energy Conversion System at Constant Wind Speed

In Figure 13 shows Wind output power at constant wind speed wind Output Power with Controller (MPPT) 8kw is output power by the help of maximum power point tracking horizontal axis represents time in seconds and vertical axis represents solar DC-Power at constant wind speed.

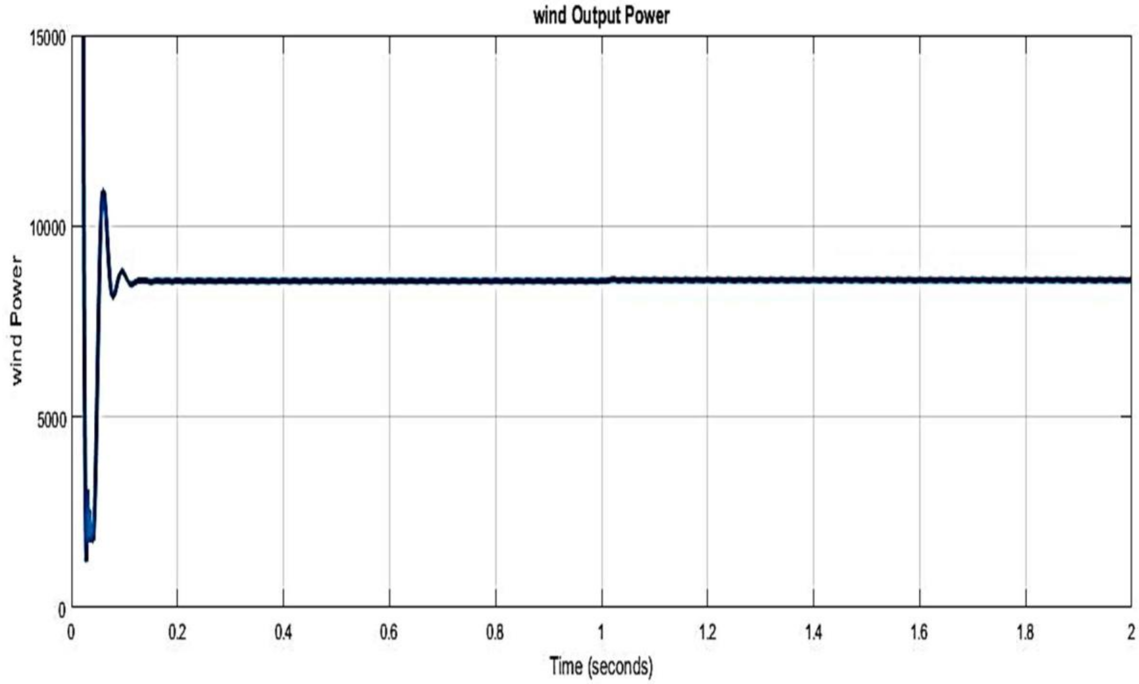

Figure 13. Wind output power at constant wind speed

In figure 14 shows Wind generator output voltage at constant wind speed. Wind output Controlled DC voltage at Wind DC side buck boost converter at constant wind speed wind Output Power with Controller (MPPT) horizontal axis represents time in seconds and vertical axis represents solar DC-Power at constant wind speed.

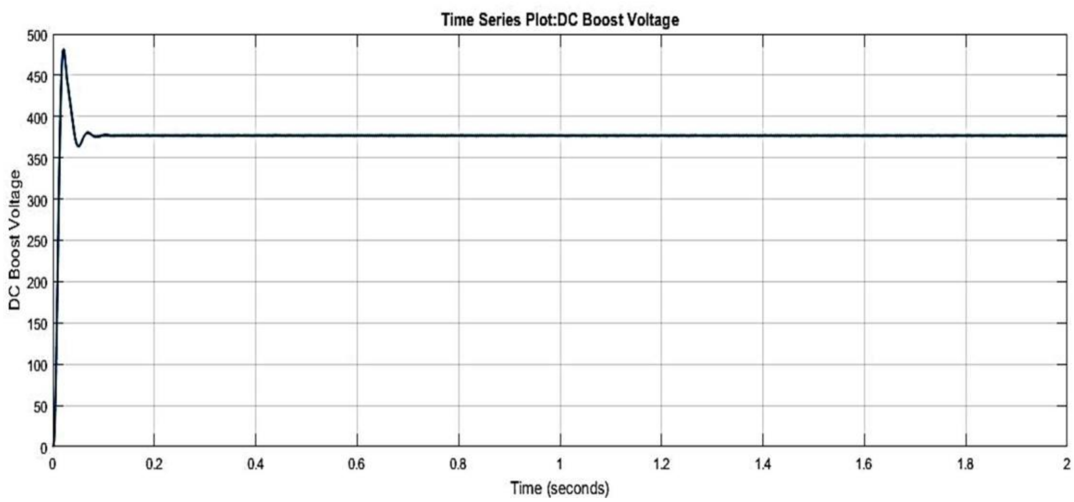

Figure 14. Wind generator output at constant wind speed

In figure 15 shows Wind boost DC current and wind boost voltage at constant wind speed. Horizontal axis represents time in seconds and vertical axis shows amplitude of DC current of wind turbine output connected with mppt buck boost converter circuit.

In figure 16 shows wind Output Power of wind turbine with Controller (MPPT) 8kw is output power by the help of maximum power point tracking in this irradiance horizontal axis represents time in seconds and vertical axis represents Wind DC-Power at constant wind speed w/m$^{2.}$

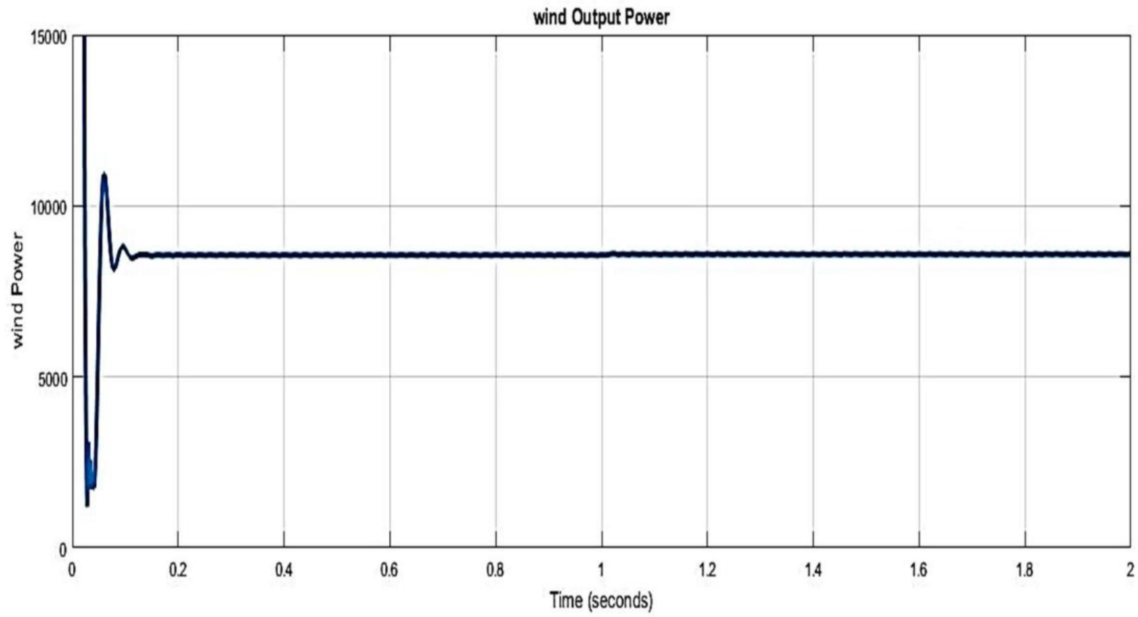

Figure 15. Wind boost DC current at constant wind speed

In figure 16 shows Permanent Magnet Synchronous Generator (PMSG) output at constant wind speed phase A Current having amplitude 8A horizontal axis represents time in seconds and vertical axis represents current amplitude.

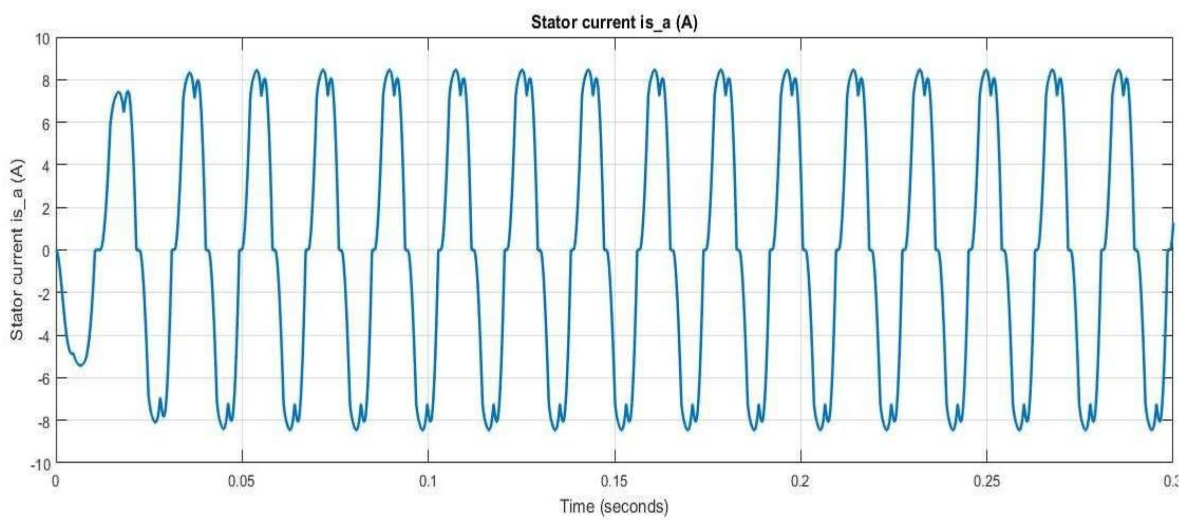

Figure 16. wind current phase B

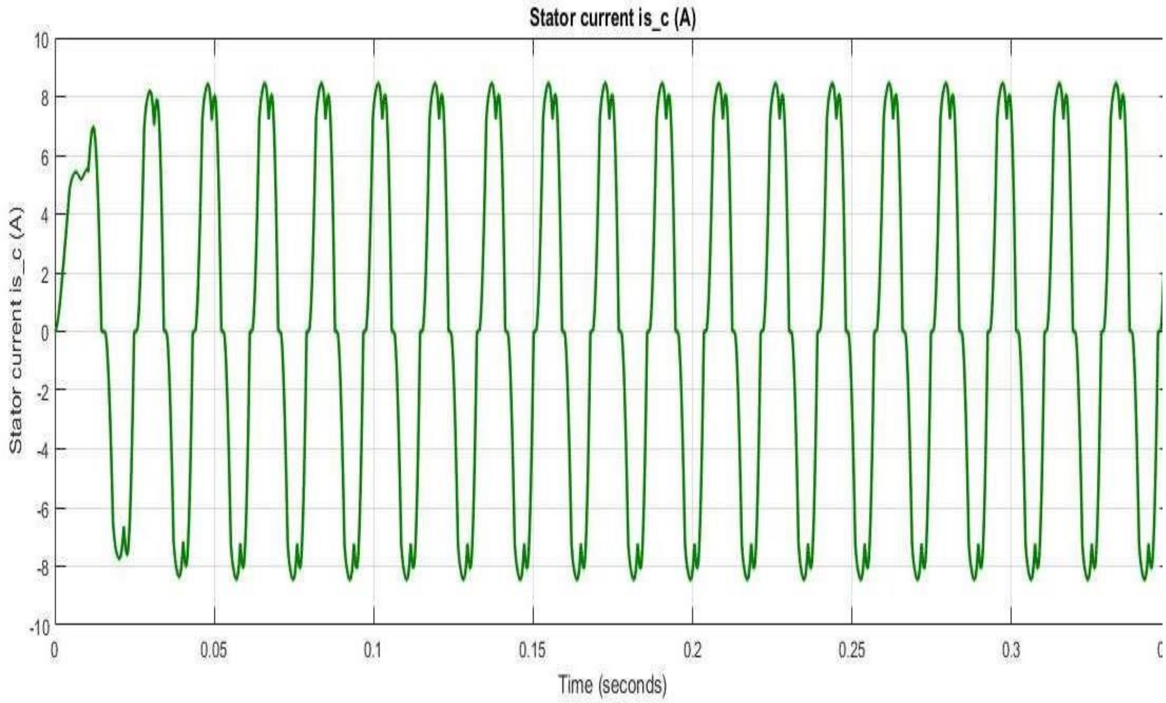

Figure 17. Wind Current Phase B

In figure 17 shows Permanent Magnet Synchronous Generator (PMSG) output at constant wind speed phase B Current having amplitude 8A horizontal axis represents time in seconds and vertical axis represents current amplitude.

In figure 18 shows Permanent Magnet Synchronous Generator (PMSG) output at constant wind speed phase B Current having amplitude 8A horizontal axis represents time in seconds and vertical axis represents current amplitude.

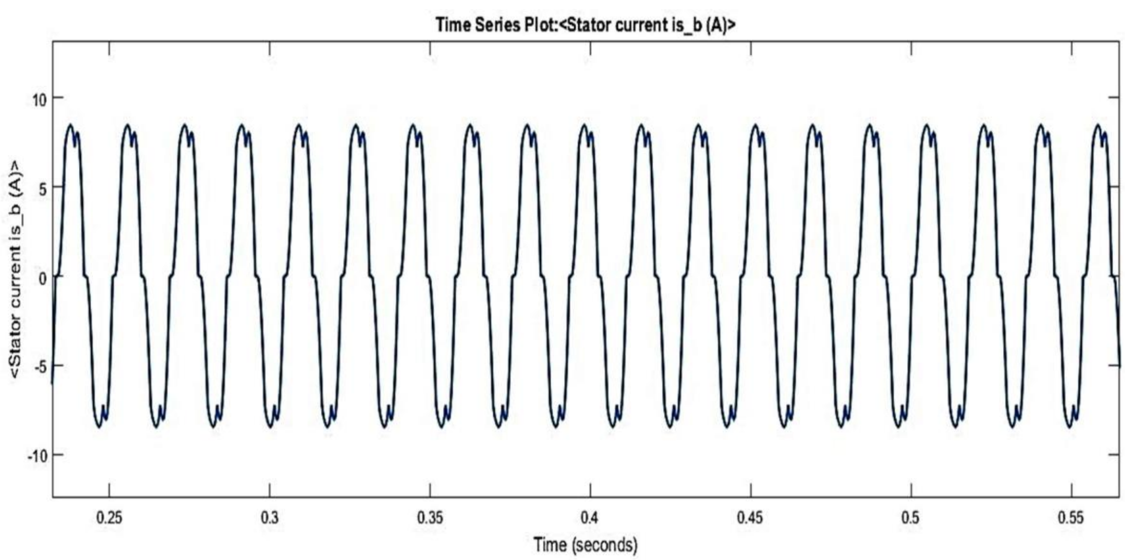

Figure 18. Wind Current Phase C

Figure 19 represents electromagnetic torque Te (N-m) of PMSG horizontal axis represents time in seconds and vertical axis represents torque and the torque magnitude is 9(N-m).

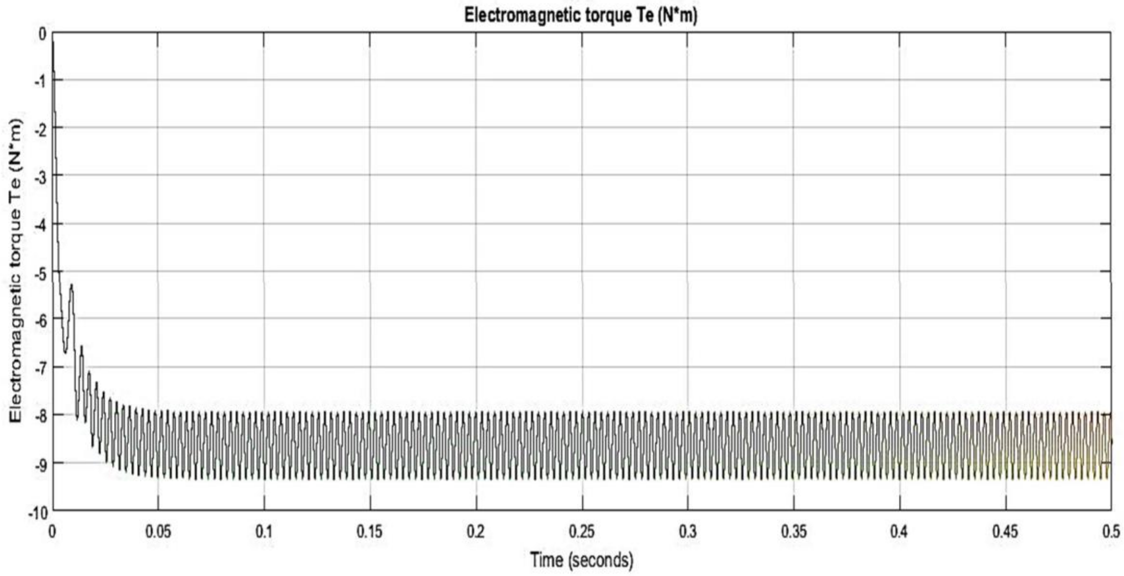

Figure 19. PMSG torque

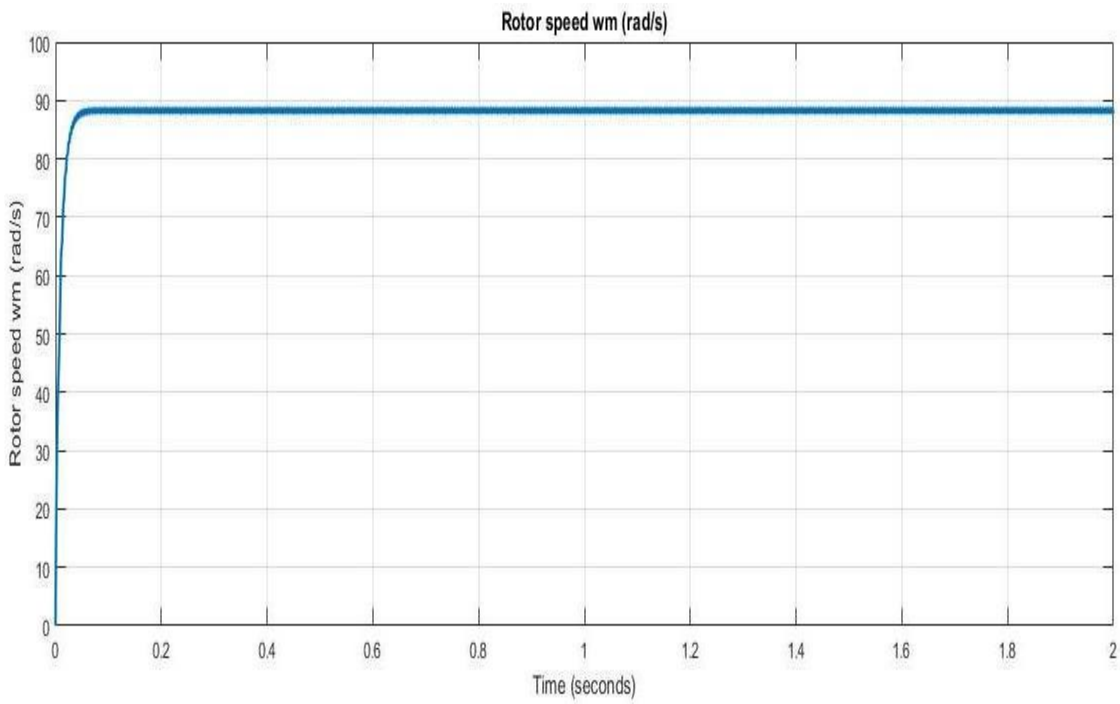

Figure 20. PMSG rotor speed (rad/sec)

Figure 20 shows permanent magnet synchrnous generator rotor speed is 90 rad/sec horizontal axis is in time in seconds and vertical represent rotor speed in rad/sec.

6. Conclusion

In this describes the Matlab based Simulink model and presents simulation results on the performance analysis of a proposed PV/Wind/Battery Hybrid Power System for household applications. The proposed system is tested for the Kuala Terengganu site in Malaysia. The objective of designing such system is to optimize the utilization RES to meet the house load demand by selecting the optimal configurations for the system. The PWB-HPS takes advantage of the complementary characteristics of solar & wind power system in which when there is no solar radiation (or poor solar radiation) the load can be supplied by wind energy and vice versa. An optimal combination and integration of PV and Wind Generation System (WGS) for a given site, a proper sizing of PV and WGS system as well as battery storage will maintain the continuity of power supply to satisfy the load demand as well as increasing the efficiency of the system. The performance of the proposed system was simulated for various models. The analysis on the simulation results shows complementary characteristics between solar and wind power system that satisfies the load demand was validated in both modes.

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